

Exercise walk-through

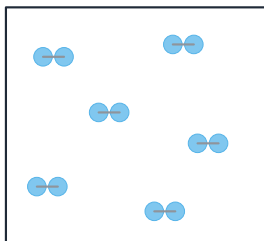
2.4

Reacting masses and volumes (of solutions and gases)

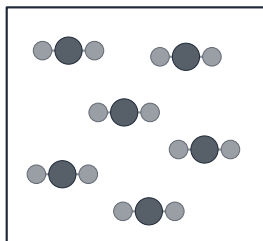
A-Level Chemistry

Gas volumes

same volume, same temperature and pressure



hydrogen, H_2



carbon dioxide, CO_2

the same **number** of molecules (6 each), even though CO_2 is bigger

Equal volumes of any gases
(same temperature & pressure)
hold equal numbers of molecules.

At r.t.p., one mole of any
gas is 24.0 dm^3 , so $n =$
 $\frac{V}{24.0}$.

The words a solution question uses

Solute and solution

Concentration is the amount of **solute** in each cubic decimetre of **solution**, in mol dm^{-3} : $c = n/V$.

State symbols

(s) solid, (l) liquid, (g) gas, and (aq) **aqueous** – dissolved in water. An equation without them is incomplete.

Excess reagent

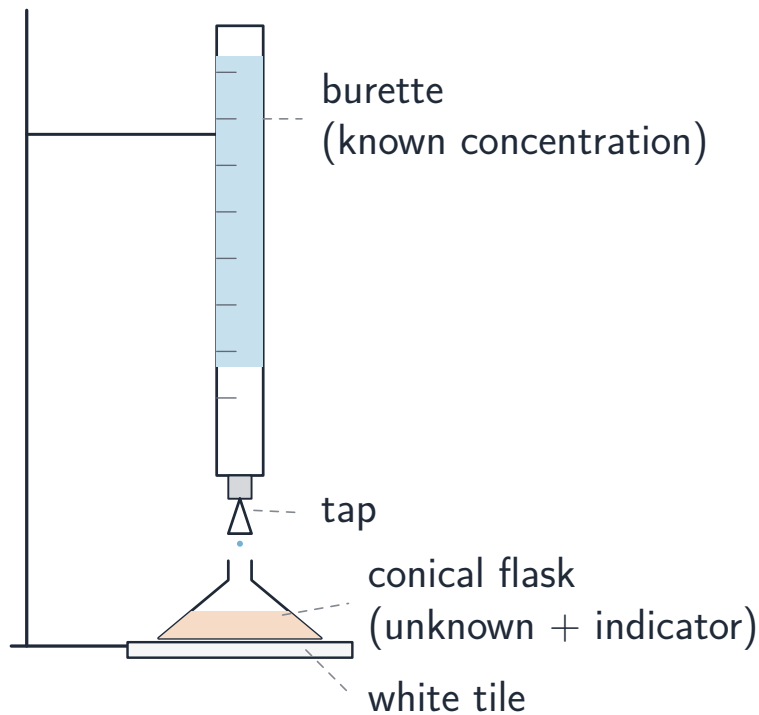
The **limiting reagent** runs out first and fixes the yield; whatever is left over is the **excess reagent**.

Hydrocarbons

For burning **hydrocarbons** – compounds of carbon and hydrogen only – compare *gas volumes* directly, since equal volumes hold equal moles.

Convert to moles first, every time. Mass, concentration and gas volume are three doors into the same room.

Titration



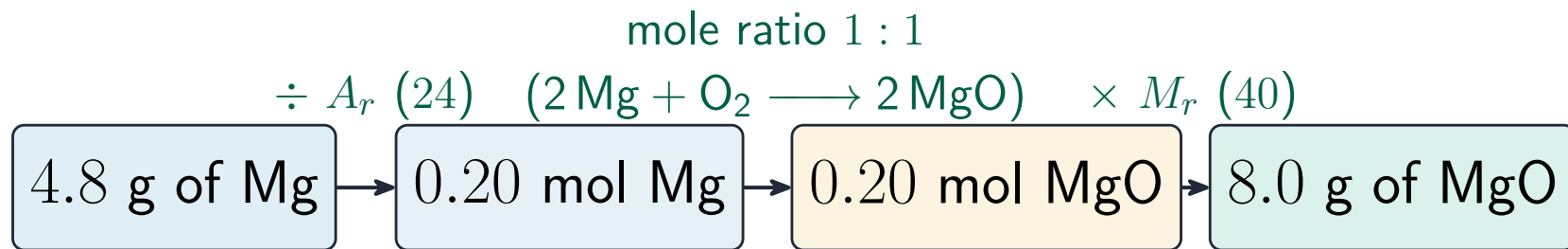
Concentration : $n = c \times V$ (in mol dm^{-3} , V in dm^3).

NaOH neutralised by HCl

20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ HCl $\Rightarrow$
NaOH = $0.0800 \text{ mol dm}^{-3}$

A **titration** finds an unknown concentration.

Reacting masses and percentage yield



mass $\rightarrow$ moles $\rightarrow$ use the equation's ratio $\rightarrow$ moles $\rightarrow$ mass

The mole bridge: mass to moles, ratio, then back to mass

Relative masses of atoms and molecules



$$A_r = \frac{(75 \times 35) + (25 \times 37)}{100} = 35.5$$

Relative atomic mass is a **weighted** average over the isotopes – chlorine is 75% ^{35}Cl and 25% ^{37}Cl , so $A_r = 35.5$. **Atoms** are far too light to weigh in grams, so every mass is compared to $\frac{1}{12}$ of a ^{12}C atom – the **unified atomic mass unit**, u.

Exercises 2.1·2.3

2.1 Calculate the mass of carbon dioxide made when 10 g of calcium carbonate decomposes: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ (M_r : CaCO_3 100, CO_2 44). [2]

2.2 Calculate the volume of 0.50 mol of gas at r.t.p. [1]

2.3 Calculate the volume of oxygen, at r.t.p., needed to burn 50 cm³ of propane completely. [2]

Exercises 2.1·2.3

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2.1

- moles $\text{CaCO}_3 = 10/100 = 0.10$; ratio 1:1
- 0.10 mol CO_2 ; $m = 0.10 \times 44 = 4.4$ g

2.2 Calculate the volume of 0.50 mol of gas at r.t.p. [1]

2.2

- $V = 0.50 \times 24.0 = 12 \text{ dm}^3$

2.3 Calculate the volume of oxygen, at r.t.p., needed to burn 50 cm^3 of propane completely. [2]

2.3

- $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$, so the volume ratio is 1 : 5; $50 \times 5 = 250 \text{ cm}^3$

Exercises 2.4-2.5

2.4 State the difference between percentage yield and atom economy. [2]

2.5 0.40 mol of N_2 reacts with 0.90 mol of H_2 to make ammonia. Identify the limiting reactant. [2]

Exercises 2.4·2.5

2.4 State the difference between percentage yield and atom economy. [2]

2.4

- Percentage yield compares the product actually obtained with the theoretical maximum, so it measures how well the reaction ran; atom economy compares the mass of the desired product with the total mass of all products, and is fixed by the equation itself

2.5 0.40 mol of N₂ reacts with 0.90 mol of H₂ to make ammonia. Identify the limiting reactant. [2]

2.5

- N₂: $\frac{0.40}{1} = 0.40$; H₂: $\frac{0.90}{3} = 0.30$; the smaller value is hydrogen, so hydrogen is limiting

Exercise 3.1

3.1 24 cm³ of methane is burned completely in oxygen: $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$.
What volume of CO₂ is made (same conditions)? [1]

☐

A 12 cm³

B 24 cm³

C 48 cm³

D 96 cm³

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A 12 cm³

B 24 cm³

C 48 cm³

D 96 cm³

3.1 B

- Ratio CH₄ : CO₂ is 1:1, so 24 cm³ of CO₂

Exercise 3.2

3.2 0.30 mol of H_2 reacts with 0.20 mol of O_2 : $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. The limiting reagent is: [1]

☐

A hydrogen

B oxygen

C water

D neither – they react exactly

Exercise 3.2

3.2 0.30 mol of H_2 reacts with 0.20 mol of O_2 : $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. The limiting reagent is: [1]

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D neither – they react exactly

3.2 A

- $0.30/2 = 0.15$ for H_2 vs $0.20/1 = 0.20$ for O_2 ; H_2 gives the smaller value, so hydrogen is limiting

Exercise 3.3 (a)

3.3 In a titration, 25.0 cm^3 of sulfuric acid is exactly neutralised by 20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ NaOH: $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$.

(a) Calculate the moles of NaOH used.

[1]

Exercise 3.3 (a)

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(a) Calculate the moles of NaOH used.

[1]

(a)

- $n = 0.100 \times 0.0200 = 2.00 \times 10^{-3} \text{ mol}$

Exercise 3.3 (b)

3.3 In a titration, 25.0 cm^3 of sulfuric acid is exactly neutralised by 20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ NaOH: $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$.

(b) Calculate the concentration of the sulfuric acid.

[3]

Exercise 3.3 (b)

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(b) Calculate the concentration of the sulfuric acid. [3]

(b)

- ratio $\text{H}_2\text{SO}_4 : \text{NaOH}$ is 1:2, so moles $\text{H}_2\text{SO}_4 = 1.00 \times 10^{-3}$; $c = n/V = 1.00 \times 10^{-3}/0.0250 = 0.0400 \text{ mol dm}^{-3}$

Exercise 3.4

3.4 8.0 g of methanol is made from a reaction whose maximum possible yield is 12.8 g. Calculate the percentage yield. [2]

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3.4

- $\frac{8.0}{12.8} \times 100 = 62.5\%$

Exercise 3.5 (a)

3.5 Ammonia is manufactured by the Haber process: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$. In one run, 2.80 kg of nitrogen is mixed with 0.750 kg of hydrogen. (A_r : N 14.0, H 1.0.)

(a) Calculate the amount, in mol, of each reactant.

[2]

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(a) Calculate the amount, in mol, of each reactant.

[2]

(a)

- $$n(\text{N}_2) = \frac{2800}{28.0} = 100 \text{ mol}; n(\text{H}_2) = \frac{750}{2.0} = 375 \text{ mol}$$

Exercise 3.5 (b)

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(b) Determine which reactant is limiting, showing your reasoning. [2]

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(b) Determine which reactant is limiting, showing your reasoning. [2]

(b)

- N_2 : $\frac{100}{1} = 100$; H_2 : $\frac{375}{3} = 125$; nitrogen gives the smaller value, so nitrogen is limiting

Exercise 3.5 (c)

3.5 Ammonia is manufactured by the Haber process: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$. In one run, 2.80 kg of nitrogen is mixed with 0.750 kg of hydrogen. (A_r : N 14.0, H 1.0.)

(c) Calculate the maximum mass of ammonia that could be formed. [3]

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(c)

- Ratio $\text{N}_2 : \text{NH}_3 = 1 : 2$, so $n(\text{NH}_3) = 200 \text{ mol}$; $M_r(\text{NH}_3) = 17.0$; $m = 200 \times 17.0 = 3400 \text{ g} = 3.40 \text{ kg}$

Exercise 3.5 (d)

3.5 Ammonia is manufactured by the Haber process: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$. In one run, 2.80 kg of nitrogen is mixed with 0.750 kg of hydrogen. (A_r : N 14.0, H 1.0.)

(d) The plant actually collects 1.02 kg of ammonia. Calculate the percentage yield. [2]

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(d) The plant actually collects 1.02 kg of ammonia. Calculate the percentage yield. [2]

(d)

- $\frac{1.02}{3.40} \times 100 = 30.0\%$

Exercise 3.5 (e)

3.5 Ammonia is manufactured by the Haber process: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$. In one run, 2.80 kg of nitrogen is mixed with 0.750 kg of hydrogen. (A_r : N 14.0, H 1.0.)

(e) Calculate the atom economy of this reaction for ammonia, and explain why it takes that value. [3]

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(e)

- Ammonia is the only product, so the atom economy is 100%; every atom of both reactants ends up in the desired product, which is characteristic of an addition or combination reaction

Exercise 3.5 (f)

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(f) Calculate the volume that the unreacted excess reactant would occupy at r.t.p. [2]

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(f)

- Hydrogen used = $3 \times 100 = 300$ mol, so $375 - 300 = 75$ mol remains; $V = 75 \times 24.0 = 1800 \text{ dm}^3$